INFLUENCE OF SHAPE ON THE CHEMICAL COMPOSITION OF POTATO TUBERS[1]

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Decided differences in the shape of potato tubers of different varieties are a matter of common knowledge. It has been suggested that these variations in shape may affect the composition of the tubers. The evidence on this, however, is conflicting.

GLYNNE and JACKSON (3), investigating the distribution of dry matter and of nitrogen in potato tubers, dissected out the different zones and analyzed them. The main regions are the medulla, or inner, and the cortex, or outer region. They found that the percentage of dry matter is lowest in the skin, increases in the cortex, and then decreases in the medulla. The nitrogen content in these three is in the reverse order to that of the dry matter. COUDON and BUSSARD (1) obtained practically the same results.

EAST (2) states that the flatter tubers have a higher starch content, because of a greater proportion of cortex. Thus, if changing the shape changes the ratios of the zones, and if the latter differ in composition, it is fair to predict that the composition of the tuber as a whole will vary with the shape. On the above lines of reasoning WILLAMAN and WEST (8, 9) concluded that the more spherical tubers would have the higher protein content.

RENSKI (6), however, found a relation opposite to that above. He reports that the longer tubers have the lower starch content. His material included many varieties over a period of several years. More recently NEUMAN (5) also reports that the longer tubers have the lower starch content. He states that high nitrogen fertilization causes an elongation of the tubers, but he does not give any data on the nitrogen content of these tubers.

During 1922 and 1923 several lots of potatoes, including several varieties, were measured as to shape, and analyzed for dry matter and nitrogen. Although the data are somewhat scanty, they point rather definitely to the conclusion that the more spherical tubers have the higher protein content. Since it is improbable that the writers will have further data in the near future, it was thought best to publish the information so far obtained.[3]

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Methods and materials

From 12 to 20 tubers were taken for a sample for analysis. The dimensions were taken in millimeters, and averaged for each lot of tubers. The tubers were scrubbed, dried, and weighed on a special balance in air and in water for determining specific gravity. Then they were shredded for analysis. Dry matter was determined on a small sample by drying at 100° C. Protein was determined on the dried and finely ground material by the Kjeldahl-Gunning method.

The five groups of samples involved were as follows, all of them grown in Minnesota:

A. Fourteen lots of Rural New Yorkers, grown in various parts of Minnesota in 1922.

B. Eight lots of Irish Cobblers grown in 1922 on peat, with various fertilizer treatments.

C. One lot each of King, Irish Cobbler, Green Mountain, Rural New Yorker, Burbank Russet, Bliss Triumph, Russet, and Early Ohio, grown on completely fertilized peat in 1922.

D. Eleven lots of Early Ohios, grown in various parts of Minnesota in 1922.

E. Twenty-six lots of Early Ohios, grown in various parts of the state in 1923.

Analysis of the results

Group E, of 26 samples, is the only one of any size for treatment statistically; since even this number is too small to justify the use of the ordinary coefficient of correlation, the coefficient of correlation by rank was calculated, using the following formula taken from JACKSON (4):

$$r = 1 - \frac{6 \Sigma D_k^2}{n(n^2 - 1)}$$

and the probable error by the formula:

$$e = 0.706 \frac{1 - r^2}{\sqrt{n}}$$

taken from WHIPPLE (7).

The results of these calculations for group E are given in table I. As has always been found by other workers, there is a high positive correlation between specific gravity and dry matter. Neither of these factors, however, appears to be related to nitrogen content or to any of the shape ratios in these samples. The nitrogen content of the fresh samples is negatively correlated with the length-depth ratio and with the width-depth ratio. In other words, the depth of the tuber is the deciding dimension; and as the depth increases, the percentage of nitrogen in the tuber as a whole increases.

TABLE I

COEFFICIENTS OF CORRELATION (BY RANK) AMONG SEVERAL FACTORS IN EARLY OHIO TUBERS (1923)

$n = 26$

	DRY MATTER	SPECIFIC GRAVITY	NITROGEN, FRESH BASIS	NITROGEN, DRY BASIS	$\frac{\text{LENGTH}}{\text{WIDTH}}$	$\frac{\text{LENGTH}}{\text{DEPTH}}$	$\frac{\text{WIDTH}}{\text{DEPTH}}$
AVERAGE WEIGHT	-0.439 ± 0.112	-0.158 ± 0.135	-0.537 ± 0.098	-0.393 ± 0.117	$+0.474 \pm 0.107$	$+0.640 \pm 0.082$	$+0.171 \pm 0.134$
DRY MATTER		$+0.742 \pm 0.062$	$+0.523 \pm 0.100$	-0.105 ± 0.137	-0.141 ± 0.136	-0.101 ± 0.137	-0.163 ± 0.134
SPECIFIC GRAVITY			$+0.363 \pm 0.120$	-0.158 ± 0.136	-0.019 ± 0.138	-0.011 ± 0.138	$+0.009 \pm 0.139$
NITROGEN FRESH BASIS					-0.182 ± 0.134	-0.333 ± 0.123	-0.345 ± 0.122
NITROGEN DRY BASIS					-0.111 ± 0.137	-0.167 ± 0.134	-0.282 ± 0.127
$\frac{\text{LENGTH}}{\text{WIDTH}}$						$+0.903 \pm 0.025$	-0.086 ± 0.137
$\frac{\text{LENGTH}}{\text{DEPTH}}$							$+0.421 \pm 0.114$

TABLE II

FOUR LOTS OF POTATO TUBERS SEGREGATED INTO "LONG" AND "SHORT" GROUPS ON BASIS OF LENGTH-WIDTH RATIO

CLASSIFICATION	RURAL NEW YORKER	IRISH COBBLER	EARLY OHIO	EARLY OHIO
	1922	1922	1922	1923
Group	A	B	D	E
No. of samples—				
Total	14	8	11	26
"Long" class	5	4	6	11
"Short" class	9	4	5	15
Length-width ratio—				
Total range	1.28–1.07	1.15–1.04	1.47–1.21	1.43–1.27
Mean of "long" class	1.27	1.12	1.44	1.40
Mean of "short" class	1.15	1.07	1.26	1.33
Difference, per cent.	– 9	– 4	– 12	– 5
Width-depth ratio—				
Total range	1.34–1.20	1.34–1.25	1.14–1.10	1.15–1.09
Mean of "long" class	1.27	1.30	1.12	1.12
Mean of "short" class	1.24	1.29	1.12	1.13
Difference, per cent.	+ 2	0	0	+ 1
Length-depth ratio—				
Total range	1.64–1.36	1.54–1.34	1.66–1.35	1.61–1.42
Mean of "long" class	1.60	1.47	1.63	1.57
Mean of "short" class	1.43	1.38	1.42	1.50
Difference, per cent.	– 10	– 6	– 13	– 4
Dry matter—				
Total range, per cent.	25.7–20.0	22.8–17.9	25.9–22.3	24.4–20.7
Mean of "long" class, per cent.	23.4	20.2	24.3	21.9
Mean of "short" class, per cent.	22.5	21.7	23.8	22.6
Difference, per cent.	– 0	+ 7	– 2	+ 3
Nitrogen, wet basis—				
Total range, per cent.	0.543–0.350	0.518–0.326	0.529–0.410	0.499–0.377
Mean of "long" class, per cent.	0.400	0.416	0.456	0.422
Mean of "short" class, per cent.	0.457	0.436	0.479	0.434
Difference, per cent.	+ 14	+ 5	+ 5	+ 3
Nitrogen, dry basis—				
Total range, per cent.	2.50–1.61	2.27–1.53	2.21–1.72	2.17–1.73
Mean of "long" class, per cent.	1.77	1.99	1.88	1.92
Mean of "short" class, per cent.	1.98	2.00	2.03	1.94
Difference, per cent.	+ 11	0	+ 8	+ 1

This relation is not so evident when the nitrogen in the dry matter is taken for comparison.

Among the shape ratios, the length-width bears a very marked relation to the length-depth; and the latter bears a significant relation to the width-depth ratio. Thus the length is the dominating dimension. Furthermore, in comparing the weight of the tubers with the shape, it is evident that as the tubers increase in size it is largely because of increased length. This is to be expected from the fact that the newly formed tuber is almost spherical. It is surprising, however, that these data indicate less dry matter in the larger tubers. This is inconsistent with the insignificant coefficient of correlation between size and specific gravity. The larger tubers apparently have a lower nitrogen content, which is consistent with the low nitrogen and long tubers. A corollary of the above facts is that the highest nitrogen content may be expected in the smaller tubers and in those of more spheroidal shape. The nitrogen content calculated to the fresh basis gives more significant coefficients than the nitrogen on the dry basis.

Groups A, B, and D, as well as group E again, were treated in a different way. The samples in each group were arranged in order of decreasing length-width ratio. Each group was then divided arbitrarily into two classes, one of high ratio and one of low. In each class the average value was calculated for each ratio, for the dry matter, and for the nitrogen content. These data are presented in table II. The class of high length-width ratio is termed for convenience the "long" class and the other the "short."

Although the number of samples in each class is small, comparisons will bring out general tendencies. Thus, the average width-depth ratios of the "long" and the "short" classes are not different, as indicated by the figures +2, 0, 0, and +1. The length-depth ratio seems to follow the length-width, however, as the differences between the two classes are −10, −6, −13, and −4 per cent. The dry matter is about the same for both "long" and "short" classes. The nitrogen on the fresh basis is consistently greater in the "short" classes. On the dry basis the tendency is less.

In table III the data are similarly arranged, but this time in respect to the width-depth ratio. Those of high ratio are called "flat," those of low ratio, "round" for convenience. Here it is seen that the nitrogen is consistently much higher in the "round" class.

In table IV the comparisons are made with respect to the length-depth ratio. Here again the "short" class contains much more nitrogen than the "long."

In all the above tables, group E exhibited the least range in shape ratios; and this explains the fact that it showed the lowest differences among the four groups in any one comparison.

TABLE III

FOUR LOTS OF POTATO TUBERS SEGREGATED INTO "FLAT" AND "ROUND" GROUPS ON BASIS OF WIDTH-DEPTH RATIO

CLASSIFICATION	RURAL NEW YORKER	IRISH COBBLER	EARLY OHIO	EARLY OHIO
	1922	1922	1922	1923
Group	A	B	D	E
No. of samples—				
Total	14	8	11	26
"Flat" class	9	2	3	17
"Round" class	5	6	8	9
Width-depth ratio—				
Total range	1.34–1.20	1.34–1.25	1.14–1.10	1.15–1.09
Mean of "flat" class	1.27	1.34	1.14	1.14
Mean of "round" class	1.21	1.29	1.11	1.11
Difference, per cent.	−5	−4	−3	−2
Length-depth ratio—				
Total range	1.64–1.36	1.54–1.34	1.66–1.35	1.61–1.42
Mean of "flat" class	1.52	1.54	1.61	1.54
Mean of "round" class	1.44	1.39	1.50	1.52
Difference, per cent.	−5	−10	−7	−1
Dry matter—				
Total range	25.7–20.0	22.8–17.9	25.9–22.3	24.4–20.7
Mean of "flat" class	23.1	21.3	23.5	22.2
Mean of "round" class	23.9	20.9	24.2	22.6
Difference, per cent.	+4	−2	+3	+2
Nitrogen, wet basis—				
Total range	0.543–0.350	0.518–0.326	0.529–0.410	0.499–0.377
Mean of "flat" class	0.417	0.370	0.445	0.420
Mean of "round" class	0.472	0.445	0.475	0.446
Difference, per cent.	+13	+20	+7	+6
Nitrogen, dry basis—				
Total range	2.50–1.61	2.27–1.53	2.21–1.72	2.17–1.73
Mean of "flat" class	1.86	1.74	1.89	1.89
Mean of "round" class	1.98	2.07	1.97	1.98
Difference, per cent.	+6	+20	+4	+5

The deductions from tables II, III, and IV are consistent throughout with those from the coefficients of correlation in table I. Thus three varieties of tubers show the same relations among the factors studied. For this reason it appeared justifiable to pool the data from all five groups, and calculate the ordinary coefficient of correlation between the nitrogen on the fresh basis and each of the shape ratios. The results are shown in table V. These coefficients on mixed varieties indicate the same relations as those on the Early Ohio alone: no significant value as regards length-width, but

TABLE IV

FOUR LOTS OF POTATO TUBERS SEGREGATED INTO "LONG" AND "SHORT" GROUPS ON BASIS OF LENGTH-DEPTH RATIO

CLASSIFICATION	RURAL NEW YORKER	IRISH COBBLER	EARLY OHIO	EARLY OHIO
	1922	1922	1922	1923
Group	A	B	D	E
No. of samples—				
Total	14	8	11	26
"Long" class	7	2	6	14
"Short" class	7	6	5	12
Length-depth ratio—				
Total range	1.64–1.36	1.54–1.34	1.66–1.35	1.61–1.42
Mean of "long" class	1.58	1.54	1.63	1.57
Mean of "short" class	1.41	1.39	1.41	1.49
Difference, per cent.	−11	−10	−13	−5
Dry matter—				
Total range	25.7–20.0	22.8–17.9	25.9–22.3	24.4–20.7
Mean of "long" class	23.6	21.3	24.3	2.21
Mean of "short" class	23.3	20.9	23.8	2.26
Difference, per cent.	−1	−2	−2	+2
Nitrogen, wet basis—				
Total range	0.543–0.350	0.518–0.326	0.529–0.410	0.499–0.377
Mean of "long" class	0.405	0.370	0.439	0.423
Mean of "short" class	0.469	0.445	0.479	0.435
Difference, per cent.	+16	+20	+9	+3
Nitrogen, dry basis—				
Total range	2.50–1.61	2.27–1.53	2.21–1.72	2.17–1.73
Mean of "long" class	1.75	1.74	1.88	1.91
Mean of "short" class	2.06	2.08	2.03	1.93
Difference, per cent.	+18	+20	+8	+1

marked negative correlation as regards length-depth and width-depth. This emphasizes again that depth is the determining dimension so far as nitrogen content is concerned.

TABLE V

COEFFICIENTS OF CORRELATION BETWEEN NITROGEN CONTENT AND SHAPE RATIOS IN POTATO TUBERS

$n = 67$

	$\frac{\text{LENGTH}}{\text{WIDTH}}$	$\frac{\text{LENGTH}}{\text{DEPTH}}$	$\frac{\text{WIDTH}}{\text{DEPTH}}$
Nitrogen (fresh basis)	$+0.0959 \pm 0.0816$	-0.2957 ± 0.0752	-0.4223 ± 0.0677

Conclusions

When the shape ratios of Early Ohio potato tubers are compared among themselves, it is found that there is a marked positive correlation between length-width and length-depth, and between length-depth and width-depth, but no relation between length-width and width-depth. Thus the length is the dominating dimension. It is also the dominating dimension when the shape ratios are compared with the size of tuber, indicating that as the tubers grow in size it is largely because of increased length. The nitrogen content of the tubers is governed more by the depth than by any other dimension. The smaller tubers tend to have a higher nitrogen content than the larger. These conclusions hold whether the comparisons are made within a variety, or among samples of tubers from several varieties.

If a variety of potato of high protein content be sought, it is believed that it will more likely be found in one having moderate sized tubers of spheroidal shape.

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